FLUID DELIVERY SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 15/012,007 filed Feb. 1, 2016, which is a continuation of U.S. patent application Ser. No. 13/858,542 filed on Apr. 8, 2013, which is a continuation of U.S. patent application Ser. No. 11/704,899 filed on Feb. 9, 2007, which claims priority from the following U.S. Provisional patent Applications, all of which are hereby incorporated herein by reference in their entireties:
Ser. No. 60/772,313 filed Feb. 9, 2006,
Ser. No. 60/789,243 filed Apr. 5, 2006; and
Ser. No. 60/793,188 filed Apr. 19, 2006.
This application may also be related to one or more of the following U.S. patent
applications filed on Feb. 9, 2007, all of which are hereby incorporated herein
by reference in their entireties:
Nonprovisional application Ser. No. 11/704,896;
Nonprovisional application Ser. No. 11/704,886;
Nonprovisional application Ser. No. 11/704,897; and

Provisional Application No. 60/889,007.

FIELD OF THE INVENTION

[0002] This application relates generally to fluid delivery systems and methods.

BACKGROUND

[0003] Many potentially valuable medicines or compounds, including biologicals, are not orally active due to poor absorption, hepatic metabolism or other pharmacokinetic factors. Additionally, some therapeutic compounds, although they can be orally absorbed, are sometimes required to be administered so often it is difficult for a patient to maintain the desired schedule. In these cases, parenteral delivery is often employed or could be employed.

[0004] Effective parenteral routes of drug delivery, as well as other fluids and compounds, such as subcutaneous injection, intramuscular injection, and intravenous (IV) administration include puncture of the skin with a needle or stylet. Insulin is an example of a therapeutic fluid that is self-injected by millions of diabetic patients. Users of parenterally delivered drugs would benefit from a wearable device that would automatically deliver needed drugs/compounds over a period of time.

[0005] To this end, there have been efforts to design portable devices for the controlled release of therapeutics. Such devices are known to have a reservoir such as a cartridge, syringe, or bag, and to be electronically controlled. These devices suffer from a number of drawbacks including the malfunction rate. Reducing the size, weight and cost of these devices is also an ongoing challenge.

SUMMARY OF THE INVENTION

[0006] In one embodiment, the present invention provides a method of dispensing fluid. In this embodiment, the method includes three processes. A first one of these processes includes pumping fluid into a resilient variable-volume dispensing chamber. The dispensing chamber is in series with a normally present finite fluid impedance and an output. The impedance is sufficient so as to cause expansion of the dispensing chamber as it receives pumped fluid even while some fluid flows through the output. Another one of these processes includes repeatedly measuring a parameter related to volume of the dispensing chamber over time. A third one of these processes includes controlling the pumping of fluid based on repeated measurements of the parameter to produce a desired fluid flow through the output.

[0007] In a related embodiment, repeatedly measuring the parameter includes acoustically exciting gas in an acoustically contiguous region to produce an acoustic response therein. The region includes a subregion coupled to the dispensing chamber so that a change in volume of the dispensing chamber causes a change in volume of the subregion. This embodiment also includes characterizing the acoustic response.

[0008] In a further related embodiment, acoustically exciting the gas is at only a single frequency. Also, characterizing the acoustic response includes determining a phase relationship between the acoustic response, as measured at a first position in the acoustically contiguous region, and a reference for the single frequency. The method of this embodiment further includes calculating a change of volume of the subregion based on temporal evolution of the phase relationship.

[0009] Alternatively or in addition, the impedance is a passive impedance. The passive impedance may optionally include a conduit. The conduit may have any of a number of forms. It may comprise coiled tubing. The coiled tubing may include at least two turns. Alternatively, or in addition, the conduit has a serpentine shape.

[0010] Also, alternatively or in addition, the conduit has a length and an internal diameter selected to provide a predetermined impedance based on at least one of a viscosity and a density of the fluid. Optionally, the internal diameter is sufficiently large as to prevent occlusion due to flow of a therapeutic liquid through the conduit. Optionally, the conduit has a length greater than 2 cm.

[0011] In a further embodiment, the method includes providing an inlet line connectable to an upstream fluid source. The inlet line is in downstream fluid communication with a pumping chamber. The pumping chamber has a pump outlet. The method also includes actuating a force application assembly so as to restrict retrograde flow of fluid through the inlet while pressurizing the pumping chamber to urge flow through the pump outlet.

[0012] In a related embodiment, actuating the force application assembly includes using travel of the force application assembly during a work stroke to restrict retrograde flow and to pressurize the pumping chamber in a single mechanical action. In a further related embodiment, a given degree of travel of the force actuation assembly restricts retrograde flow, and a greater degree of travel pressurizes the pumping chamber.

[0013] In a further related embodiment, actuating the force application assembly includes restricting retrograde flow toward the fluid source by occluding the inlet line. Alternatively or in addition, the method also includes preventing reverse flow of fluid from a dispensing chamber into the pumping chamber by using a passive valve placed therebetween.

[0014] In another related embodiment, a portion of the pumped fluid may be allowed to return to a fluid source (e.g.,